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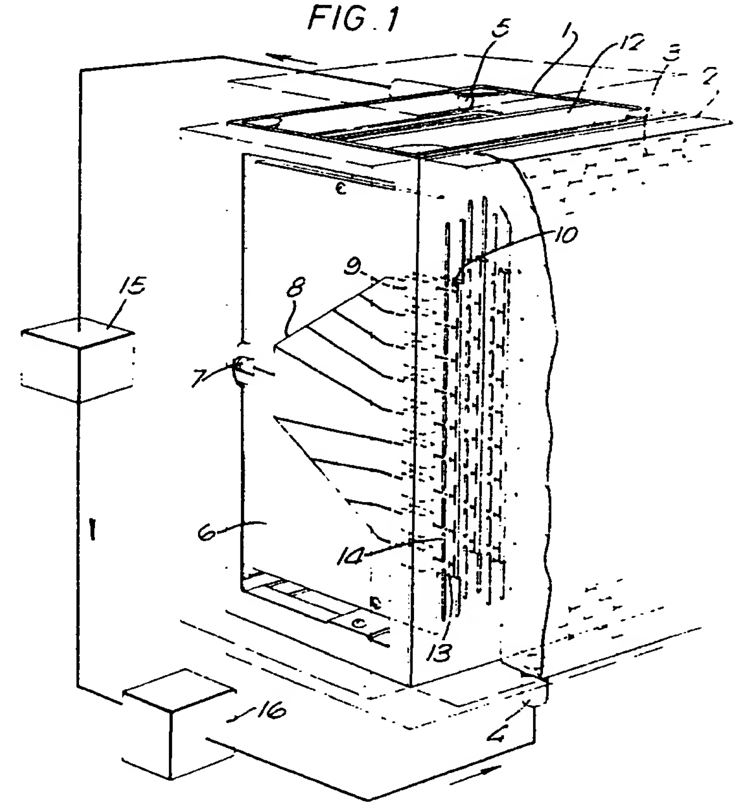
(54) An antenna

(57) The performance of a phased array antenna may be degraded by dispersion in the transmission paths and by losses of energy as heat. These problems are resolved by the incorporation of superconductive components which are cooled by the passage of liquid nitrogen through the antenna enclosure. The antenna may include both superconducting striplines 8 and superconducting dipoles 10.

FIG. 1



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy

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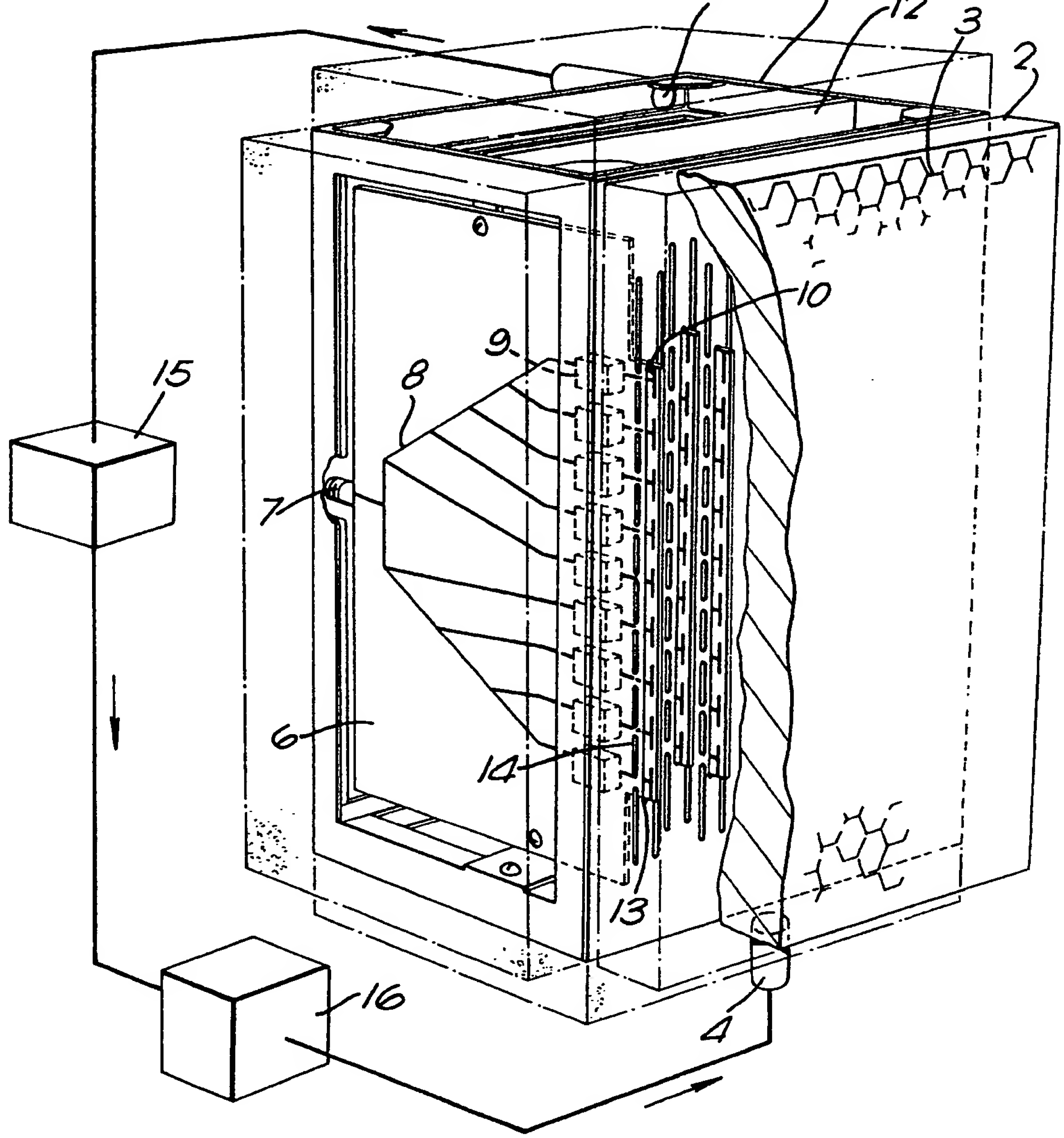
FIG. 1



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Antenna

This invention relates to an antenna comprising an array of radiating or receiving elements. It arose in the design of an antenna having an array of dipoles arranged in an array of rows and columns, each column of dipoles being fed by a stripline or microstrip feed arrangement.

Such known arrangements suffer from a problem in that the feeds have a significant impedance which is different for different frequencies, resulting in degradation of transmitted or received signals.

The discovery of rare earth superconductors with a critical temperature Tc below the temperature of liquid nitrogen has made their use in antenna feasible. Below Tc, the substance exhibits the properties associated with superconductors, that is zero electrical resistance and low dispersion which means that they pass a range of frequencies equally well.

The invention arose from a realisation that these properties could be used with beneficial effect to reduce the problem mentioned above.

This invention provides an antenna comprising an array of radiating or receiving elements connected to superconductive feeds.

For superconductors to remain superconducting they must remain at a temperature below that of Tc. So if superconductors are to be used in phased array antennas as elements or striplines they must be enclosed in thermally insulated enclosures and cooled with liquid nitrogen.

Some conventional phased array antennas are protected from the weather by box-like enclosures comprising a frame clad with panels of foamed plastics material reinforced by an aluminium honeycomb. Fortunately the panels have the good thermally insulating properties required for insulating the coolant. This box-like enclosure is thus ideally adaptable to contain coolant for producing the superconducting properties. Preferably the elements are dipoles and since the conventional box-like enclosure encloses the dipole or other elements in addition to the feeds, the former can conveniently also be made superconductive, further reducing losses and dispersive effects.

However, problems can arise in ensuring an adequate circulation of liquid nitrogen especially to those components that produce the most heat. In a preferred arrangement a reflective ground plane positioned behind the elements is used to divide the enclosure into two parts or chambers.

This ground plane has, in the preferred arrangement, apertures for the passage of coolant between the chambers. The apertures can advantageously be arranged so as to direct the coolant between boards carrying the superconductive feeds. Furthermore they can be arranged so as to produce proportionally greater cooling of components or parts which require it. The apertures, are preferably slots to maximise flow of coolant. These slots are preferably aligned with a plane of polarization of

the elements to minimise interference with the reflective function of the ground plane. Preferably the flow of coolant is from front to back so as to produce streams of coolant flow over the parts that most require it. Advantageously the coolant may be recycled.

A specific embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawing which shows a phased array antenna constructed in accordance with the invention and incorporating superconducting striplines, dipoles and a slotted groundplane.

Referring to the drawing, the illustrated phased array antenna comprises an enclosure produced by cladding a frame 1 with heat insulation panels 2. The front panel is of a honeycomb structure 3 designed to be transmissive to microwave energy. The other panels can be of similar material or of foamed plastics material. The enclosure has an inlet 4 at the lower front of the enclosure through which liquid nitrogen coolant is pumped. The coolant exhausts from the enclosure by outlet 5.

The enclosure contains a plurality of parallel vertical boards 6. Each board has a co-axial socket 7 attached to its rear edge. A signal to be transmitted is applied to each socket 7, via superconducing striplines 8 carried by the boards 6 and a plurality of transmit/receive modules 9 also carried by the boards 6, to elements 10. Each transmit/receive module 9 contains a superconducting phase shifter, and other components which

produce heat namely a power amplifier and a limiter circuit.

The elements 10 in this embodiment are superconducting dipoles but in alternate embodiments may be other superconducting elements suitable for receiving or transmitting signals such as loop elements. Received signals pass from the elements 10 to the sockets 7 in the reverse manner.

In order that the antenna radiates in a direction generally forward of the antenna only, a groundplane 12 is employed. Each board 6 is positioned so that its end portion carrying the dipoles 10 passes through a slot 13 in the groundplane. This is a continuous linear slot as shown but in alternative embodiments may be a series of slots to allow the dipoles 10 individually to pass through.

The groundplane 12 separates the enclosure into two compartments. In order that coolant may flow between the compartments a series of slots 14 are produced in the groundplane 12. The orientation of these cooling slots 14 is such as to match the plane of polarization of the dipoles 10. If the beam were desired to have a horizontal polarization the slots would have to extend in a horizontal direction. In this way the groundplane 12 has the same property of directing all the radiative energy forward as if the slots had not been made. Further the cooling slots 14 are disposed parallel to and between the boards 6 so as to direct the coolant over the

transmit/receive modules 9 thereby ensuring that the phase shifters within them remain superconducting despite their proximity to the power amplifiers, which are the circuits that produce the greatest amount of heat.

In an alternative embodiment the sizes and/or distribution of the slots over the area of the ground plane can be selected to give a greater flow of coolant near the centre of the groundplane or at other places where it is found that an accumulation of heat would otherwise result.

The coolant passes over the modules 9, striplines 8 and board 6 to outlet 5 where it is exhausted from the enclosure. The coolant in this case nitrogen, then passes to a compressor 15 where it is liquified, and a heat exchanger 16 where it is cooled. It then passes, through inlet 4, to the enclosure where it is allowed to evaporate. In this way all the superconducting components have their temperature maintained below that of their critical temperature Tc.

CLAIMS

1. An antenna comprising an array of radiating or receiving elements connected to superconductive feeds.

2. An antenna as claimed in claim 1 enclosed in a heat insulated enclosure with means for passing coolant into the enclosure.

3. An antenna as claimed in claim 1 or 2 in which the elements are superconductive.

4. An antenna as claimed in claim 3 when dependent on claim 2 having a reflective ground plane behind the elements, which divides the enclosure into two chambers and has apertures allowing passage of coolant between the chambers.

5. An antenna according to claim 4, in which the superconductive feeds are formed on boards having spares between them and in which the apertures in the ground plane are positioned so as to direct the coolant into the spaces.

6. An antenna as claimed in claim 4 in which the feeds include, or are connected to, components or parts which would, without cooling, become relatively hot and in which the apertures are arranged so as to expose those components to a proportionally greater flow of coolant.

7. An antenna as claimed in claim 5 or 6 in which the apertures are slots aligned with a plane of polarization of the elements.

8. An antenna as claimed in any one of claims 4 to 7 in which the flow of coolant is from front to back.

9. An antenna as claimed in any previous claim in which the elements are dipoles.

10. An antenna as claimed in any preceding claim in which the coolant is recycled.

11. An antenna as claimed in any preceding claim in which the coolant is liquid nitrogen.

12. An antenna substantially as herein described with reference to the drawing.

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